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ROTATION SENSOR WITH TEMPERATURE MEASURING FEATURE

Technical Field

The present invention relates generally to methods and apparatus for acquiring temperature information in the proximity of a variable reluctance sensor, for example a rotation sensor associated with the bearings of a vehicle wheel, and in particular, to a method and apparatus for utilizing the properties of the variable reluctance sensor, such as a vehicle anti-lock braking system passive sensor located inside a vehicle wheel bearing, to provide a temperature dependant signal representative of the temperature at the variable reluctance sensor location.

Background Art

Many automotive vehicle of current manufacture come equipped with antilock braking systems and some with traction control systems as well. In a vehicle so equipped, the systems monitor the rotation of some, if not all, of the wheels – and certainly, the front wheels which steer the vehicle. Should a wheel begin to slip when the brakes are applied, as could well occur if the wheel encounters snow or ice, the antilock braking system will detect the loss of velocity and relax the braking forces on that wheel. This allows the wheel to continue to rotate and enables the driver to maintain better control over the vehicle. On the other hand, if one of the driving wheels encounters slippery pavement and as a consequence loses traction, the traction control system will apply a braking force to that wheel, and this has the effect of transferring the torque to the opposite wheel which perhaps has better traction.

An antilock braking system or traction control system for a vehicle thus requires speed sensors to monitor the rotation of some, if not all, wheels on the vehicle. While a variety of locations exist on a vehicle for installation of a speed sensor for a wheel, perhaps the best is in the housing that contains the bearing on which the wheel, or more accurately, the hub for the wheel, rotates. This keeps much of the sensor isolated from contaminates and objects that might otherwise

housing, this classical solution requires a separate electrical circuit for the temperature sensor signals, resulting in an increase in cost and additional susceptibility to wear or damage.

Systems which utilize properties of the antilock braking system or traction control system to provide a signal representative of vehicle wheel bearing temperature, such as shown in U.S. Patent No. 5,381,090 to *Adler et al.* are known. In the '090 *Adler et al.* patent, the changes in direct current electrical resistance of the speed sensor windings responsive to the temperature of the associated wheel bearing and components are measured by applying a voltage to the speed sensor windings. The resulting output signal is a combination of the magnetically induced AC voltage representative of the vehicle wheel speed, and a DC voltage representative of temperature. Additional circuit components, including particularly active components are provided to filter the resulting output signal and provide a modified output signal in the form of a square wave output having a frequency related to vehicle wheel speed, together with a separate DC voltage for enabling temperature sensing.

It would be advantageous to provide a temperature sensing system for use in conjunction with existing variable reluctance sensors, such as those found in vehicle wheel bearings. A temperature sensing system utilized with existing vehicle antilock braking system (ABS) or traction control (TC) system passive variable reluctance sensors, which does not modify the magnetically induced AC voltage output signals which are representative of the vehicle wheel speed, would permit a bearing temperature sensing system to be retrofitted and installed inside the vehicle wheel bearings of vehicles without significant alteration to the vehicle wiring harness and electrical components. It would be particularly advantageous for applications where the ABS passive variable reluctance sensor is located inside the vehicle wheel bearing, as the temperature of the passive variable reluctance sensor correlates

traction control system existing sensor through the Wheatstone bridge circuit.

In an alternate embodiment of the present invention, the temperature sensing system includes an constant voltage source, such as a voltage regulator, operatively coupled to the antilock braking system or traction control system existing sensor through a Wheatstone bridge circuit. Selection of resistors placed in the Wheatstone bridge circuit permits a bias adjustment of a DC voltage representative of sensed temperature. A filter circuit is coupled to one node of the Wheatstone bridge circuit to provide the magnetically induced AC voltage output signals representative of the vehicle wheel speed, while a comparator circuit is coupled between a pair of nodes of the Wheatstone bridge circuit to provide a temperature limit warning signal to a vehicle operator for example, on a special display on the vehicle dashboard.

The foregoing and other objects, features, and advantages of the invention as well as presently preferred embodiments thereof will become more apparent from the reading of the following description in connection with the accompanying drawings.

Brief Description of Drawings

In the accompanying drawings which form part of the specification:

Figure 1 is an electrical schematic of a conventional wheel speed sensor unit;

Figure 2 is an electrical schematic of an idealized representation of a conventional wheel speed sensor unit, illustrating a real coil as a pure coil in serial with a pure resistor;

Figure 3 is a simplified electrical schematic representation of a constant voltage source coupled to the wheel speed sensor unit of Fig. 2 using a drop resistor;

one skilled in the art to make and use the invention, describes several embodiments, adaptations, variations, alternatives, and uses of the invention, including what is presently believed to be the best mode of carrying out the invention.

Turning to Figures 1-3, a speed sensor 10 includes a stationary probe 12 which is presented toward a target wheel or “tone ring” (not shown) that rotates with a road wheel and contains discontinuities, such as teeth, which the stationary probe 12 detects as the target wheel revolves. The result is a pulsating signal, which reflects the angular velocity of the wheel.

Conventional stationary probes 12 are variable reluctance sensors consisting of a coil with a magnetic core. As the tone ring rotates in front of the magnetic core, and the alternation of discontinuities changes the magnetic flux lines, a resulting alternating current induces a voltage in the coil. This voltage has a frequency corresponding to the number of discontinuities passing the stationary probe 12 per second, and can be related to the angular speed of the vehicle wheel or to the speed of the vehicle.

As shown specifically in Figure 2, the stationary probe 12 can be represented by a pure coil L in series with a pure resistor R, having a temperature dependence coefficient. To monitor the temperature of the stationary probe 12, it is known to superimpose to the magnetically induced AC voltage signal a DC signal that varies with the temperature of the stationary probe 12. As is described generally in U.S. Patent No. 5,381,090 to *Adler, et al.*, this may be done by wiring a voltage source 16, as shown in Figure 3, to the stationary probe 12.

In Figure 3 a constant voltage source 16 is shown coupled to the wheel speed sensor unit of Fig. 2 using a drop resistor RV1. The drop resistor RV1 is preferably adjustable to accommodate sensor resistance tolerances. Since the resistance value R of the coil is highly and linearly temperature dependant, the DC voltage at node SN1 is correspondingly temperature dependant. Furthermore at SN1, the AC component

Turning to Figure 5, in an embodiment 100 of the present invention, the voltage signals at sensing node SN1, shown in Figure 6, represent a superposition of the DC temperature dependant signal and the AC in the coil induced voltage. To analyze and use both pieces of information, each signal is separated to provide a pure DC signal to analyze the sensor coil temperature and a pure AC signal to feed the ABS ECU. Components used to separate the superimposed AC voltage (ABS information) from the DC voltage (temperature information) at node SN1 define two filters. The first filter, consisting of resistor R4 coupled between nodes SN1 and SN3, and a capacitor C1 coupled between nodes SN3 and SN6, provides a pure DC voltage, independent from the alternating current ABS signal. The pure DC voltage signal is representative of only the temperature information.

A second filter consisting of a second capacitor C2 provides a pure AC signal between nodes SN4 and SN1, as shown in Figure 7. The pure AC signal is representative of the original ABS signal to be sent to the ECU. Using only passive circuit components such as resistor R4 and capacitors C1 and C2 to separate the pure AC and DC signals greatly reduces associated component costs.

An alternate embodiment 200 of the present invention is shown in Figure 8. A second branch with a pair of resistors R1 and R2 is added in parallel with the voltage source 16, forming a Wheatstone bridge configuration with the variable reluctance sensor (R and L) and the resistor RV1 in a first branch, and resistors R1 and R2 in a second branch. The Wheatstone bridge wiring circuit provides the ability to establish a DC bias signal, shown in Figure 9, for the temperature information circuit. Resistors R1, R2, and RV1 can be selected to obtain a DC voltage signal of a specific value for a specific temperature of the sensor resistor R. When the circuit 200 is used to measure the temperature of a wheel bearing or other component, the bias permits the DC voltage signals to be adjusted to obtain a 0.0 mV output at a temperature of either 0°C or 0°F when the temperature signal is

example, a resistance value approximately equal to the nominal resistance value of the stationary probe 12 at the ambient temperature, permitting the ECU to check for damage in the wiring 402 leading to R6, because the capacitors C3 and C4 block DC voltage signals. Capacitor C4 may be optional, depending if ground continuity is required for the particular application in which the system is utilized.

However, with resistor R6 having roughly the same ohmic value as the sensor, the AC ABS signal voltage will drop and result in approximately a 50% reduction in the magnetically induced AC voltage signal. To compensate for the reduction caused by the addition of resistor R6, the voltage signal at node SN4 is routed through a voltage follower U2 to adapt this new load impedance. The additional capacitor C3 acts to prevent additional problems during a resistance test by the vehicle control module. An other optional capacitor C4 can be introduced for the same reasons, if galvanic insulation is desired between ECU circuit and the new electronic in front of R6. In this embodiment 400, R6 fed by the capacitors C3 and C4 with the pure AC ABS signal to function as a coil emulator, and to pass to the ECU a copy of the original magnetically induced AC ABS voltage signal from the sensor.

However, those of ordinary skill in the art will recognize that tests for correct resistance ranges performed by the ECU could fail to detect problems with the circuits disposed in front of resistor R6. To avoid this, it may be observed that in case of short-cut in the sensor coil or in his wiring 404 to nodes SN1 and SN6, the DC temperature signal between nodes SN3 and SN2 will reach a negative value outside of a predetermined range. The same situation would occurs if the coil or the associated wiring to nodes SN1 and SN6 is cut, however, in this case the DC temperature signal would reach an abnormal high value outside of the predetermined range. Optionally, a min / max detector consisting of two comparator circuits would permit detection of any additional problem in the sensor and associated wiring circuit by comparing the DC

original ABS or TCS magnetically induced AC voltage signal on at a separate point from the temperature dependant DC voltage signal, and cleanly extracts each signal from the other, thereby permitting the temperature sensing system 400 to be easily fitted to existing vehicle wiring systems. If required, depending upon the particular vehicle configuration, additional circuits, such as the voltage follower U2 and differentiator U1 may be provided to accommodate specific signal requirements for individual vehicle control modules.

For applications requiring only a determination of whether a predetermined maximum temperature limit has been reached, for example, to avoid damage to a wheel bearing, the differentiator circuit U1 on Figure 13 can be replaced by a simple comparator to trigger an alarm device, alerting the driver of an abnormal temperature in a bearing. In this case the bias circuit consisting of resistor R1 and resistor R2 is set to define the upper temperature limit to trigger the alarm device.

In a further alternate embodiment, those of ordinary skill in electrical circuit design will recognize that the voltage follower U2 and associated components C3, C4, and R6 may be replaced by an LF transformer to perform an equivalent function.

For practical application in an vehicle, the temperature sensing systems 100, 200, 300 or 400 of the present invention can be readily adapted to couple between existing vehicle wheel bearing speed sensors and vehicle control modules, without altering existing vehicle wiring or modifying the vehicle control module. The present invention provides the original magnetically induced AC voltage signal, representative of vehicle wheel speed, to the vehicle control module without the superimposed temperature dependant DC voltage signal. For an alternative application, the vehicle control module may be modified to include the necessary electronic circuits to implement the temperature sensing system 100, 200, 300 or 400 of the present